A national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy

NREL National Renewable Energy Laboratory

Innovation for Our Energy Future

Interconnection: National Codes & Standards Development and Implementation -- IEEE* SCC21 1547 Series of Interconnection Stds and More

Colorado Workshop on Interconnection and Net Metering
Feb. 22, 2006

Tom Basso - Secretary IEEE SCC21/1547
NREL** Interconnection Engineering and Standards

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* Institute of Electrical and Electronic Engineers (IEEE)
Standards Coordinating Committee 21 (SCC21)
** National Renewable Energy Laboratory (NREL)
Distributed Energy & Electricity Reliability Program,
US DOE Office of Electricity Delivery & Energy Reliability

IEEE

NREL

OUTLINE

- **Summary Presentation: slides 3 – 24**
- **Background**
- **1547 Interconnection Series of Stds**
  - IEEE Std 1547 (2003): Standard for interconnecting (system and interconnection test requirements and specifications)
  - IEEE Std 1547.1 (2005) Standard for interconnection conformance test procedures
  - P1547.2 Guide to 1547 standard - ballot targeted fall 2006
  - P1547.3 Guide for information exchange for DR interconnected with EPS – ballot planned march 2006
  - P1547.4 Guide for DR island systems
  - P1547.5 Guide for interconnection to transmission grid
  - P1547.6 Recommended Practice for DR in Distribution Networks
- **Adopting Standards:**
  - Testing & Certification
  - Implementation Rules and Agreements

Summary

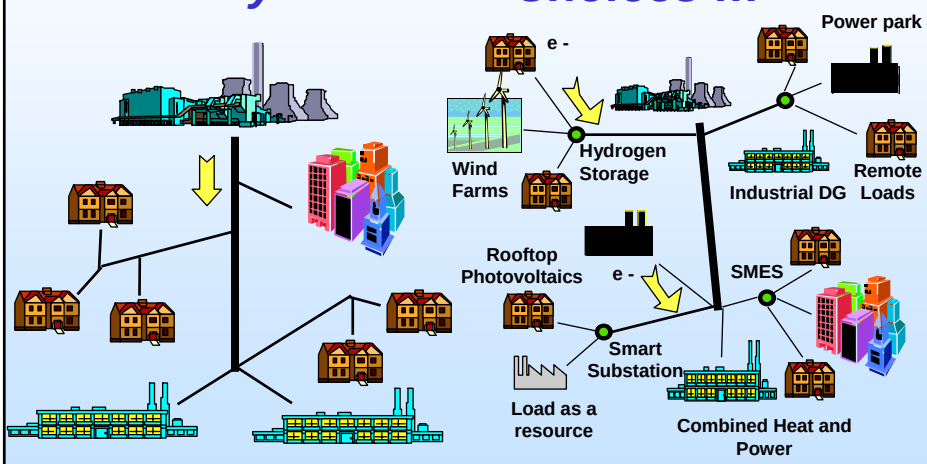
- **Grid Modernization: Distributed Energy Resources**
- **1547 Series of Standards Developed:**
  - **Industry driven partnerships a success for stakeholders.**
  - **DOE/NREL support IEEE industry driven efforts.**
  - **IEEE Std 1547 and IEEE Std 1547.1 -- American National Standards Published 800-678-4333, http://shop.ieee.org/store**
  - **IEEE Draft P1547.2 application guide – ballot targeted fall 2006;**
  - **IEEE Draft P1547.3 DR communications – ballot March 2006**
- **1547 Standards Being Implemented**

– USA federal Energy Policy Act 2005 cites and requires IEEE standards 1547; PJM, MADRI, and states adopting 1547; interconnection testing and certification.

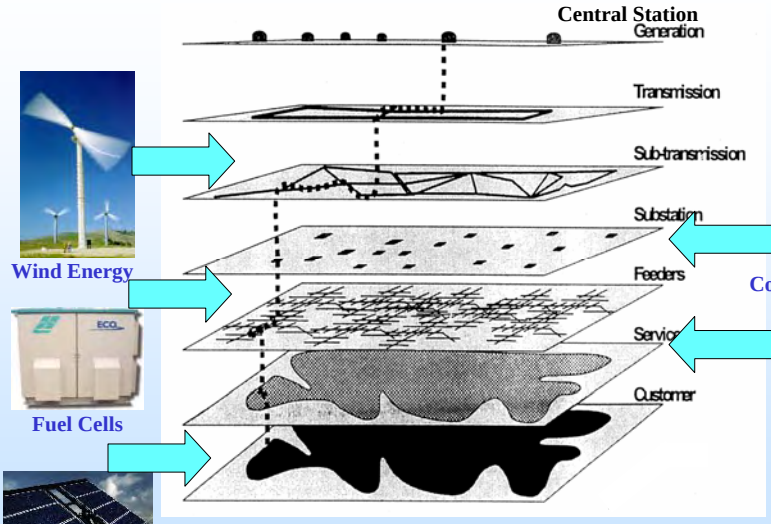
Grid Modernization

Today's Electricity …

Tomorrow's Choices …



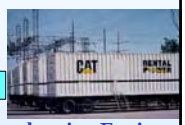
Interconnecting Distributed Systems



Wind Energy

Fuel Cells

Solar Energy



Combustion Engines

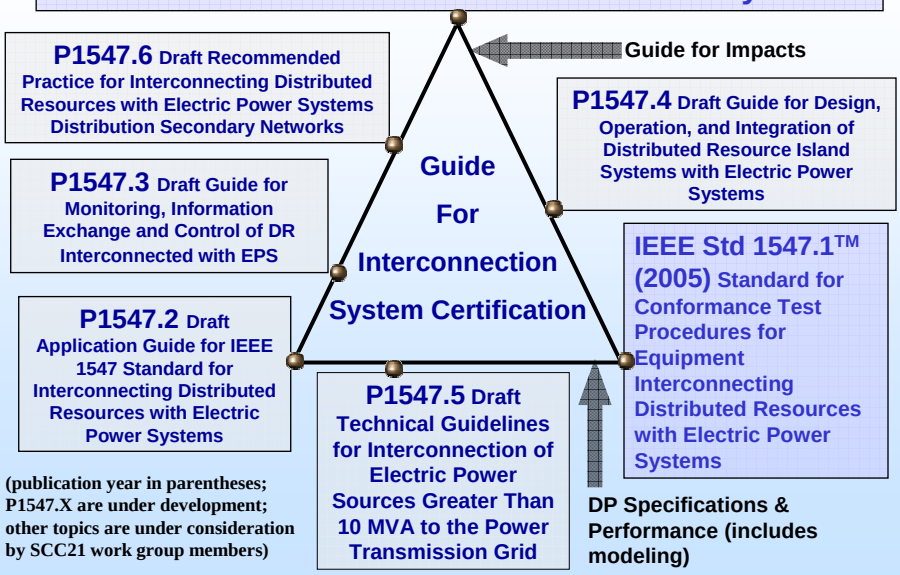
MicroTurbines

The overall power system is traditionally viewed in terms of 7 layers; each performing its function from central station generation supplying power out to customers.

Federal 2005 Energy Policy Act Cites & Requires IEEE Stds 1547 (IEEE 1547 Developed By National Team of 444 Professionals)

IEEE SCC21 1547 Series of Interconnection Standards

IEEE Std 1547™ (2003) Standard for Interconnecting Distributed Resources with Electric Power Systems



P1547.6 Draft Recommended Practice for Interconnecting Distributed Resources with Electric Power Systems Distribution Secondary Networks

P1547.4 Draft Guide for Design, Operation, and Integration of Distributed Resource Island Systems with Electric Power Systems

P1547.3 Draft Guide for Monitoring, Information Exchange and Control of DR Interconnected with EPS

IEEE Std 1547.1™ (2005) Standard for Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems

P1547.2 Draft Application Guide for IEEE 1547 Standard for Interconnecting Distributed Resources with Electric Power Systems

P1547.5 Draft Technical Guidelines for Interconnection of Electric Power Sources Greater Than 10 MVA to the Power Transmission Grid

(publication year in parentheses; P1547.X are under development; other topics are under consideration by SCC21 work group members)

American National Standards ANSI/IEEE 1547 Series of Standards

IEEE Std 1547 (2003) – Requirements

Affirmative IEEE Ballot February 2003

- Voting Membership
  - 230 members (31% general interest, 4% government, 30% manufacturer/producer, 35% utility/user)
  - 91% affirmatives
- **444 Work Group & Ballot Group Members at time of ballot**

American National Standard designation ANSI/IEEE Std 1547 - October 20, 2003

IEEE Std 1547.1 (2005) – Test Procedures

Affirmative IEEE Ballot February 2005 - published July 2005

- Voting Membership
  - 118 members
  - 95% affirmatives

IEEE 1547 IS:

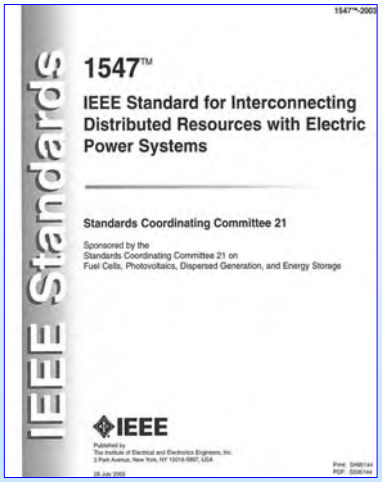
- **A Technical Standard – Functional Requirements For**
  - the interconnection itself
  - the interconnection test
- **Technology neutral,** e.g., does not specify particular equipment nor type
- **A single (whole) document** of mandatory, uniform, universal, requirements.
- **Should be sufficient** for most installations.

IEEE 1547.1 IS:
Test Procedures
Conformance to 1547

IEEE 1547 Is NOT:

- a design handbook
- an application guide
- an interconnection agreement
- prescriptive, e.g., does not address DR self-protection, nor planning, designing, operating, or maintaining the Area EPS.

American National Standard ANSI/IEEE Std 1547



Contents

IEEE Std 1547.1 Test Procedures …

this standard specifies the type, production, and commissioning tests that shall be performed to demonstrate that interconnection functions and equipment of a distributed resource (DR) conform to IEEE Std 1547.

…

5.0 Type (Design) Tests

- 5.1 Temperature Stability
- 5.2 Response to Abnormal Voltage
- 5.3 Response to Abnormal Frequency
- 5.4 Synchronization
- 5.5 Interconnection Integrity
- 5.6 DC injection
- 5.7 Unintentional Islanding
- 5.8 Reverse Power
- 5.9 Cease to Energize Functionality and Loss of Phase
- 5.10 Reconnect Time
- 5.11 Harmonics
- 5.12 Flicker

6 - Production Tests

7 - Commissioning Tests

- **Verification and Inspections**
- **Field Conducted type and Production Tests**

UL 1741 Standard

Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources

- NREL contracted with UL to update 1741 to include all DER interconnections.
- UL 1741 Goes beyond 1547 requirements to include product safety aspects; doesn't incorporate all of 1547
  - Construction, Materials, wiring, component spacing, etc.
  - Protection against risks of injury to persons
  - Output Characteristics and utility compatibility

    (This section includes requirements from IEEE 1547)
  - Rating, Marking
  - Specific DR Tests for various technologies

    (PV, Wind, Microturbine, Fuel Cell, Engine)

How do these standards work together ?

NREL Interconnection Certification Approach

IEEE 1547
Interconnection System and Test Requirements

- Voltage Regulation
- Grounding
- Disconnects
- Monitoring
- Islanding
- etc.

IEEE 1547.1
Interconnection System Testing

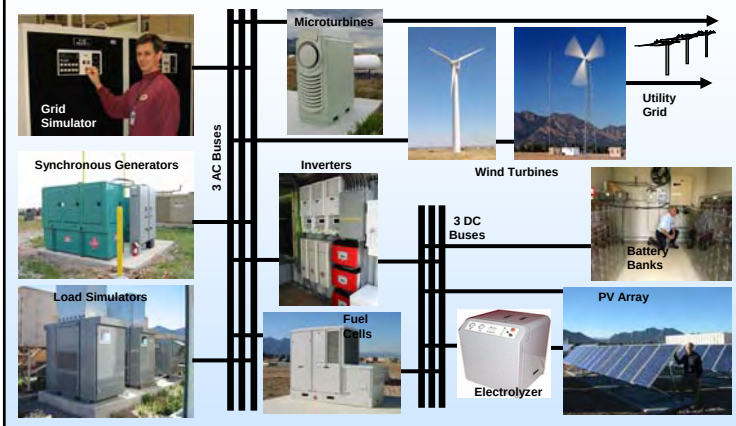
- O/U Voltage
- and Frequency
- Synchronization
- EMI
- Surge Withstand
- DC injection
- Harmonics
- Islanding
- Reconnection

UL 1741*
Interconnection Equipment

- 1547.1 Tests
- Construction
- Protection against risks of injury to persons
- Rating, Marking
- Specific DR Tests for various technologies

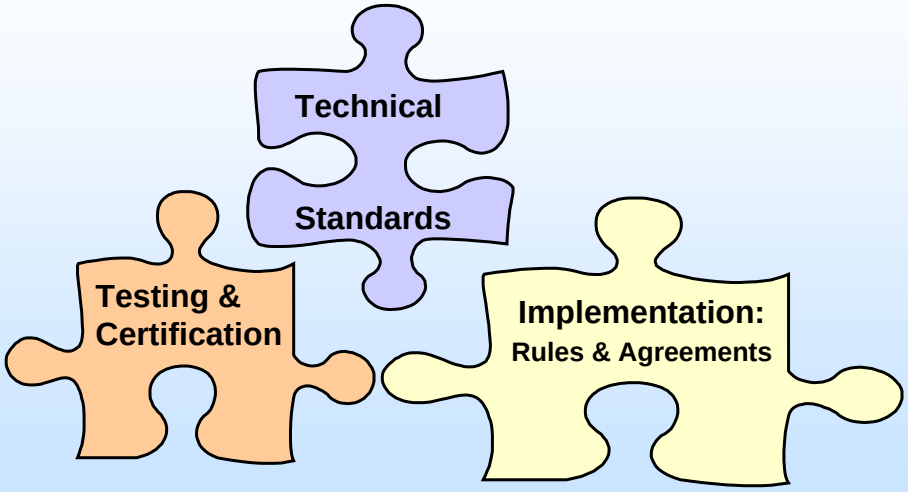
* Conformance to subset of 1547

NREL DER Test Facility



- Test Systems up to 200kW
- Natural Gas on site
- All DER Technologies

Interconnection: *Putting the Pieces Together*



Interconnection is Not A Simple Issue

- Electric Power Systems Not Designed for Distributed Energy Resources, especially two-way power flow.
- Selling power into the grid was not a major issue until 1970's (PURPA).
- Interconnection requirements are far from standard.
- USA Federal Energy Policy Act 2005 Cites and Requires IEEE Standards 1547

IEEE 1547 Takes Us A Long Way, But …

- States individually implementing approaches
- Utilities and manufacturers: multi-state or multi-national
- Only recently: national mandate for implementation
  - Utilities required to use 1547 series of stds
- Different ways of implementing IEEE 1547
- How to ensure validity, quality and consistency?
  - Incorporate or Mandate 1547 standards
  - Certification of Equipment based on 1547
  - Standardized Interconnection Rules/Procedures
  - Authorities having jurisdiction; assessor; arbitrator/etc.

Interconnection Testing & Certification

Interconnection Testing Standards

- IEEE 1547 (Requirements)
- IEEE 1547.1 (Test Procedures)
- UL 1741 (Equipment construction, marking, etc.)

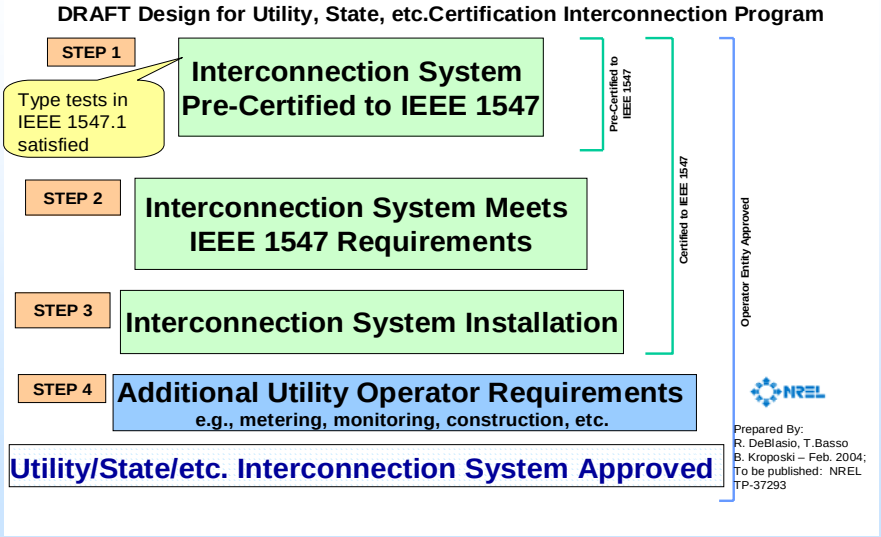
Interconnection Test Facilities

- NREL Test Facility
- Others, e.g., UL, DUIT, etc.

Potential for future work

- facilitate certification protocol development and implementation
- options for certifying small generators (less than 10 MW)
- options for maintaining a registry of this equipment

NREL Model 1547 Pre-certification and Certification Program for DG Interconnection Systems



PJM Interconnect * Small Generator Std

(FERC approved 2005)

- **Two Major Goals** (2 MW DG expanding to 10 MW)
  - *Standardize interconnection requirements, based on IEEE 1547, throughout PJM business domain*
  - *Ensure test compliance to IEEE 1547*
- **PJM initiative allows pre-certification**

*** PJM Interconnect is a Regional Transmission Organization RTO with over 110 GW load**

**** Technical Support by DOE/NREL**

MADRI Model Interconnection Procedures

(Nov'05: Mid-Atlantic Distributed Resources Initiative)

Foster regional consistency among states' small generator interconnection procedures across Mid-Atlantic region.

Two Key Considerations:

- Technical Standards (establish common requirements for DG interconnection)
- Implementation Procedures (establish common rules and agreements for DG interconnection)

What's Next?

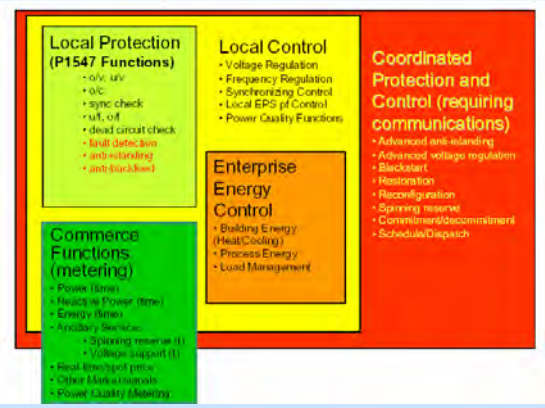
- Complete the IEEE Std 1547 series of guides and recommended practices
- Reaffirm and update 1547 requirements and tests
- Validate equipment certification, laboratory accreditation, and certification registries
- Harmonize individual states interconnection process/rules, (e.g., MADRI model in mid-Atlantic states such as PA, DE, MD, DC)
- Support other states/regions
- PJM completes 10 MW std based on IEEE 1547
- Start interconnection activities with non-PJM Regional Transmission Operators

P1547.2 Ballot Targeted Fall 2006

IEEE P1547.2 *application guide* to 1547 (ballot targeted fall 2006). "guide" offers alternate approaches – e.g., practical applications guidance, tips, techniques and rules of thumb for applying IEEE 1547 to specific interconnection situations on specific utility distribution feeders. Industry identified this as critically important practical companion to 1547.

Example of an alternate approach to 1547 requirements.

(Graphic From "Universal Interconnection Technology (UIT) Workshop Proceedings" NREL/BK-560-32865.)



P1547.3 Ballot Planned March 2006

P1547.3 guide to information exchange, monitoring and control for DR; "guide" offers alternate approaches – e.g., power industry communications guidance for specific cases of DR interconnection situations.

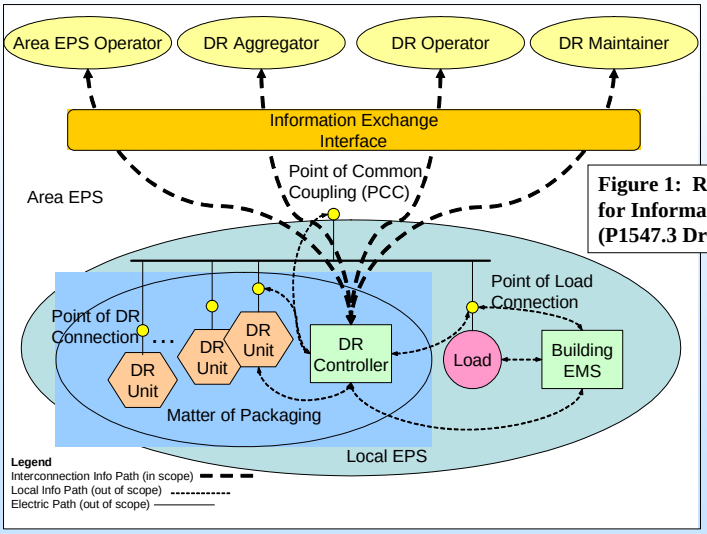


Figure 1: Reference Diagram for Information Exchange (P1547.3 Draft 1/06)

Questions?

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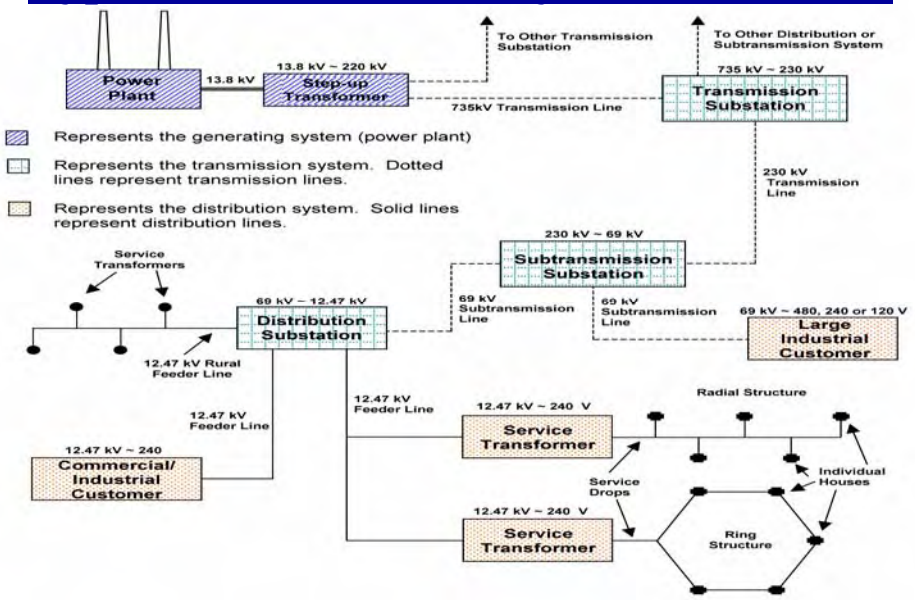
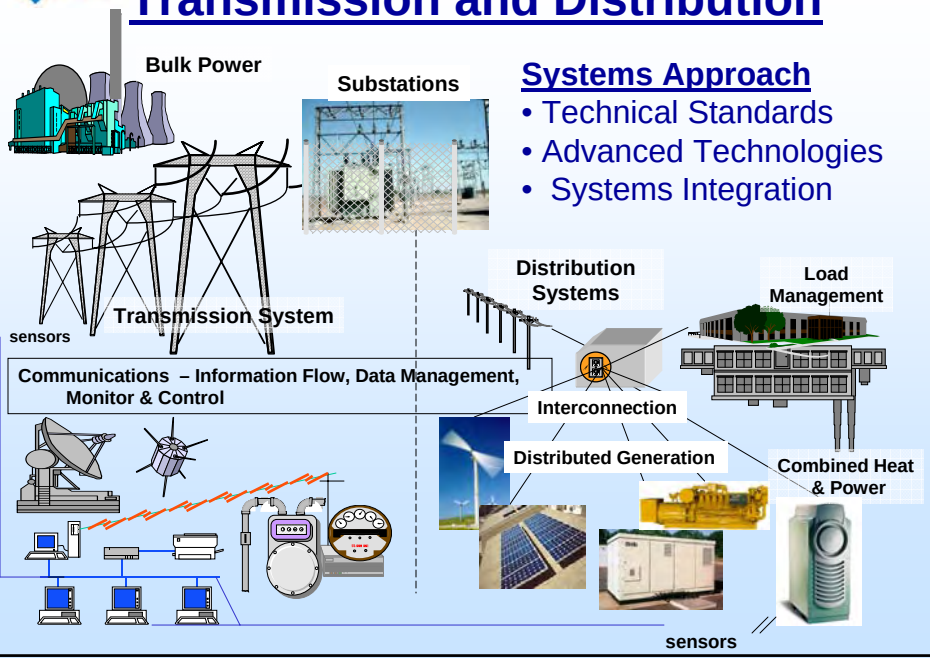
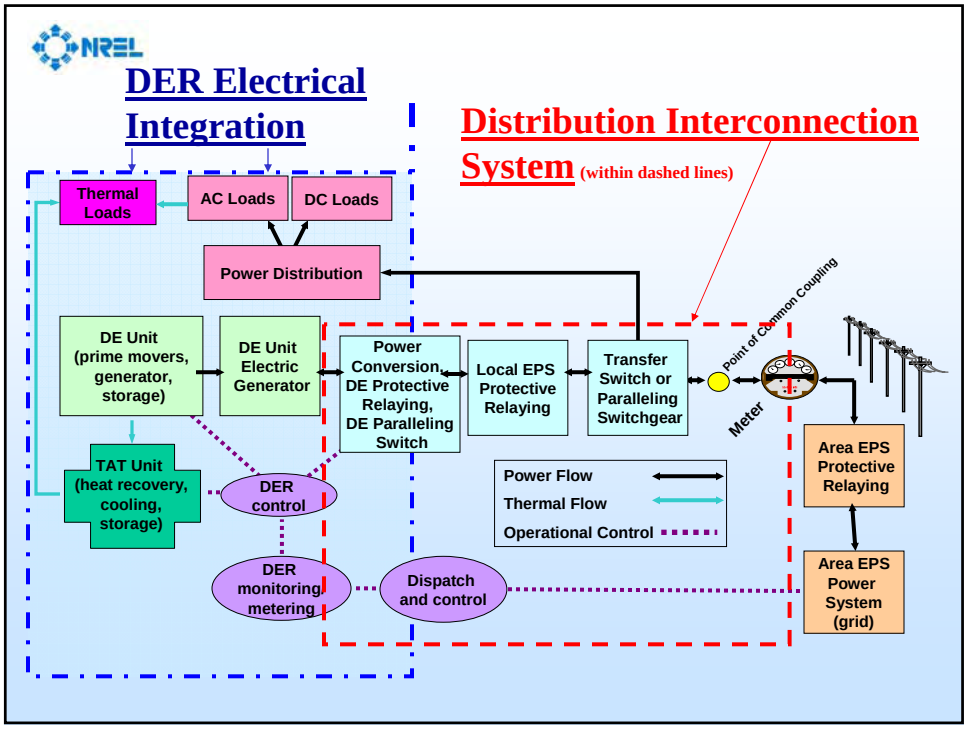
Typical Electric Power System in the USA

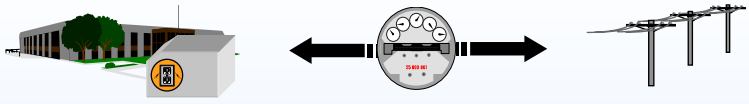


Transmission and Distribution





DER Opportunities and Benefits



Potential Consumer Benefits

- Clean energy
- Lower cost electricity
- Reduced price volatility
- Greater reliability and power quality
- Energy and load management
- Combined Heat and Power

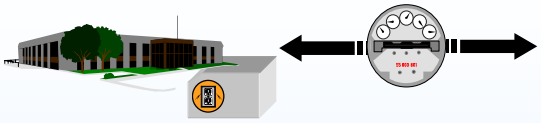
Potential Supplier Benefits

- Reduced electric line loss
- Reduced T&D congestion
- Grid investment deferment and improved grid asset utilization
- Improved grid reliability
- Ancillary services, e.g., voltage support and stability, VARs, contingency reserves, and black start capability

➔Greater flexibility and energy security←

Proven technologies, customer choice, open market access, and easy interconnection are required to achieve these benefits

Standards Benefits



- Safeguards against hazards
- Fosters quality design and manufacture
- Increases competitiveness in industry
- Creates and expands markets
- Facilitates Trade and Commerce
- Assurance is provided when products meet quality standards, then users need not be concerned with redundant testing or evaluation of the product

- Accelerates engineering advances & implementation, interoperability, and installation
- Assists increased quality and reliability achievement
- Simplifies compliance to needs, permitting, & rules
- Promotes advanced communications; software platforms interchangeability
- Enables enhanced DR systems and grid intelligence
- Lower cost and quicker deployment for projects.

Standards Development

- **National consensus standards** established via industry driven partnerships; balanced stakeholder participation.
- **Harmonization of national and international standards, codes, and certification/laboratory accreditation**, e.g., International Electro-technical Commission (IEC) dual logo arrangement for IEC to adopt IEEE standards for electronics, telecom, and power generation.
- **IEEE SCC21** – sponsors standards development (Chair: R. DeBlasio)
- **IEC TC 8 *System Aspects of Electrical Energy Supply*:** TC8 facilitates functioning of electricity supply systems – systems encompass T&D networks including interfaces with user installations (generators and consumers) US/TAG & Technical Advisor: T. Basso.
- **IEC TC 82 *Photovoltaics*** – US Secretariat (NREL support).
- **IEC Joint Coordinating Group** (JCG) on Distributed Rural Electrification Systems for international activities (R. DeBlasio invited/originating Chair; JCG organization structure modeled on IEEE SCC21/1547).

Institute of Electrical and Electronic Engineers - IEEE_

- IEEE - international technical professional society
- More than 375,000 members from 150 countries
- Advances the theory and application of electro-technologies and allied sciences
- Produces over 30% of world's published literature in electrical engineering, computers, and controls
- One of the pre-eminent standards bodies

IEEE Definitions/Protocols

IEEE Classification of Standards Documents

Standards: documents with mandatory requirements (shall).

Recommended Practices: documents in which procedures and positions preferred by the IEEE are presented (should).

Guides: documents in which alternative approaches to good practice are suggested but no clear-cut recommendations are made (may).

IEEE Ballot Consensus

Voter group balanced: each interest group < 50% of total (users, manufacturers, general interest); voter may provide comments, sponsor responds to each negative stating sponsor position on comments, sponsor re-circulates unresolved negatives to allow balloters to change their vote; minimum of 75% affirmation needed to pass to IEEE Standards Board for their approval.

IEEE Standards Board

- Approves all IEEE standards projects and standards for publication.
- Establishes Standards Coordinating Committees (SCC) that report directly to Board.
- Established IEEE liaison to DOE (R. DeBlasio, Chair SCC21)
- IEEE standards are recognized nationally and worldwide
  - IEEE standards may qualify as American National Standard (ANSI/IEEE status)
  - IEEE and IEC dual logo arrangement

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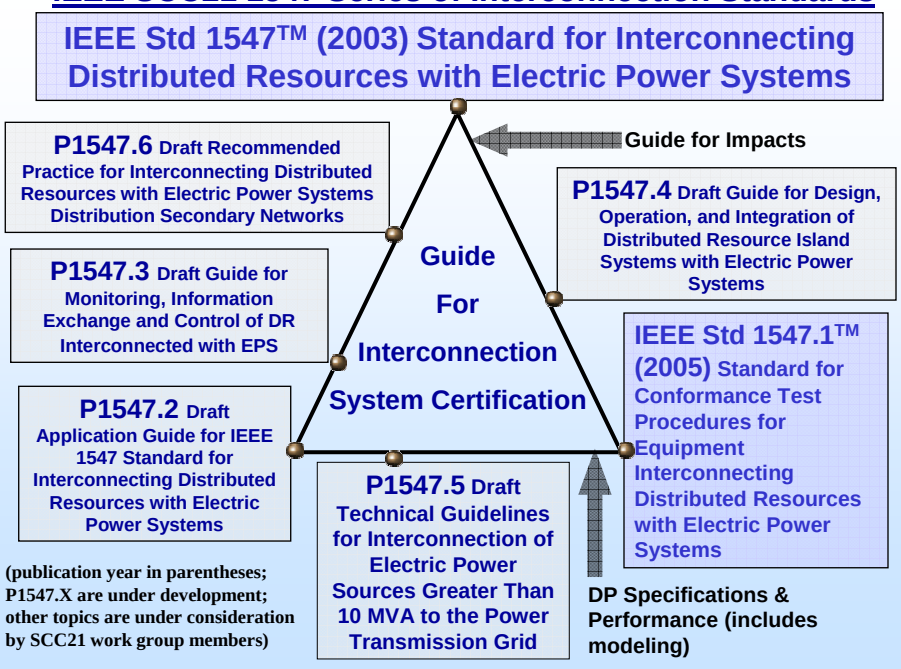
IEEE Standards Coordinating Committee 21

SCC21 *Fuel Cells, Photovoltaics, Dispersed Generation, & Energy Storage*

- Scope and Purpose.
- SCC21 Oversees the development of standards in the areas of Fuel Cells, Photovoltaics, Dispersed Generation, and Energy Storage, and coordinates efforts in these fields among the various IEEE Societies and other affected organizations to ensure that all standards are consistent and properly reflect the views of all applicable disciplines.
- SCC21 reviews all proposed IEEE standards in these fields before their submission to the IEEE-SA Standards Board for approval and coordinates submission to other organizations.

IEEE SCC21 1547 Series of Interconnection Standards



Current SCC21 Interconnection Projects

Title	Scope & Purpose
IEEE Std 1547™ (2003) Standard for Interconnecting Distributed Resources with Electric Power Systems	• This Standard establishes criteria and requirements for interconnection of distributed resources (DR) with electric power systems (EPS). • This document provides a uniform standard for interconnection of distributed resources with electric power systems. It provides requirements relevant to the performance, operation, testing, safety considerations, and maintenance of the interconnection.
IEEE Std 1547.1 (2005) Standard for Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems	• This Standard specifies the type, production, and commissioning tests that shall be performed to demonstrate that interconnection functions and equipment of a distributed resource (DR) conform to IEEE Std 1547. • Interconnection equipment that connects distributed resources (DR) to an electric power system (EPS) must meet the requirements specified in IEEE Standard 1547. Standardized test procedures are necessary to establish and verify compliance with those requirements. These test procedures must provide both repeatable results, independent of test location, and flexibility to accommodate a variety of DR technologies.

Current SCC21 Interconnection Projects

Title	Scope and Purpose
P1547.2™ Draft Application Guide for IEEE Standard 1547 for Interconnecting Distributed Resources with Electric Power Systems	• This Guide provides technical background and application details to support the understanding of IEEE 1547 Standard for Interconnecting Distributed Resources with Electric Power Systems. • This document facilitates the use of IEEE 1547 by characterizing the various forms of distributed resource technologies and the associated interconnection issues. Additionally, the background and rationale of the technical requirements are discussed in terms of the operation of the distributed resource interconnection with the electric power system. Presented in the document are technical descriptions and schematics, applications guidance and interconnection examples to enhance the use of IEEE 1547.
P1547.3™ Draft Guide for Monitoring, Information Exchange and Control of Distributed Resources Interconnected with Electric Power Systems	• This document provides guidelines for monitoring, information exchange, and control for distributed resources (DR) interconnected with electric power systems (EPS). • This document facilitates the interoperability of one or more distributed resources interconnected with electric power systems. It describes functionality, parameters and methodologies for monitoring, information exchange and control for the interconnected distributed resources with, or associated with, electric power systems. Distributed resources include systems in the areas of fuel cells, photovoltaics, wind turbines, microturbines, other distributed generators, and, distributed energy storage systems.

Current SCC21 Interconnection Projects

Title	Scope and Purpose
P1547.4 ™ Draft Guide for Design, Operation, and Integration of Distributed Resource Island Systems with Electric Power Systems	• This document provides alternative approaches and good practices for the design, operation, and integration of distributed resource (DR) island systems with electric power systems (EPS). This includes the ability to separate from and reconnect to part of the area EPS while providing power to the islanded local EPSs. This guide includes the distributed resources, interconnection systems, and participating electric power systems. • This guide is intended to be used by EPS designers, operators, system integrators, and equipment manufacturers. The document is intended to provide an introduction, overview and address engineering concerns of DR island systems. It is relevant to the design, operation, and integration of DR island systems. Implementation of this guide will expand the benefits of using DR by targeting improved electric power system reliability and build upon the interconnection requirements of IEEE 1547.

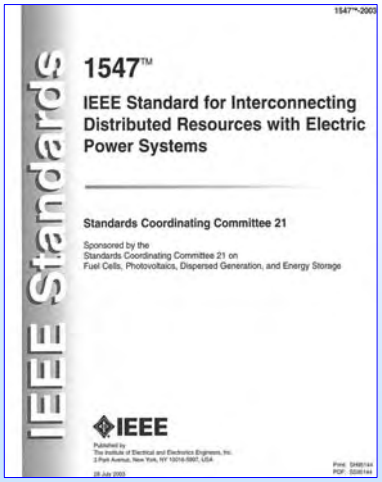
Current SCC21 Interconnection Projects

Title	Scope and Purpose
P1547.5 Draft Technical Guidelines for Interconnection of Electric Power Sources Greater Than 10 MVA to the Power Transmission Grid	• This document provides guidelines regarding the technical requirements, including design, construction, commissioning acceptance testing and maintenance /performance requirements, for interconnecting dispatchable electric power sources with a capacity of more than 10 MVA to a bulk power transmission grid. • The purpose of this project is to provide technical information and guidance to all parties involved in the interconnection of dispatchable electric power sources to a transmission grid about the various considerations needed to be evaluated for establishing acceptable parameters such that the interconnection is technically correct.
P1547.6 Draft Recommended Practice for Interconnecting Distributed Resources With Electric Power Systems Distribution Secondary Networks	• This standard builds upon IEEE Standard 1547 for the interconnection of distributed resources (DR) to distribution secondary network systems. This standard establishes recommended criteria, requirements and tests, and provides guidance for interconnection of distribution secondary network system types of area electric power systems (Area EPS) with distributed resources (DR) providing electric power generation in local electric power systems (Local EPS). • This standard focuses on the technical issues associated with the interconnection of Area EPS distribution secondary networks with a Local EPS having DR generation. The standard provides recommendations relevant to the performance, operation, testing, safety considerations, and maintenance of the interconnection. In this standard consideration is given to the needs of the Local EPS to be able to provide enhanced service to the DR owner loads as well as to other loads served by the network. Equally, the standard addresses the technical concerns and issues of the Area EPS. Further, this standard identifies communication and control recommendations and provides guidance on considerations that will have to be addressed for such DR interconnections.

1547 Development Approach

- **IEEE Std 1547 (2003)** (Interconnection Standard) -- start March 1999; Chair: R. DeBlasio, NREL; > 500 volunteers developed or balloted std.
- **IEEE Std 1547.1 (2005)** (Test Standard) -- start June 2001; Chair: J. Daley, ASCO Power Technologies, Inc., 82 members; balloted fall 2004.
- P1547.2 (Guide to Std 1547) -- start Dec. 2001, ballet targeted fall 2006; Chair: N. R. Friedman, Resource Dynamics Corporation, 96 members.
- P1547.3 (Guide for Monitoring, Information Exchange, and Control) -- start June 2002, ballot planned March 2006; Chair: F. Goodman, EPRI, 95 members.
- P1547.4 (DR Islanding Systems) – start Dec. 2003; Chair: B. Kroposki, NREL, 75 members.
- P1547.5 (Interconnection >10 MVA to Transmission Grid) – start Sept. 2004; Chair: M. N. Satyanarayan, Xcel Energy (membership open).
- P1547.6 (DR on Secondary Networks) – start Mar 2005; Chair: J. L. Koepfinger, IEEE Standards Board Emeritus (50 members).
- IEEE/1547 members identified additional priority standards needs (e.g., see 1547 series graphic).

American National Standard ANSI/IEEE Std 1547



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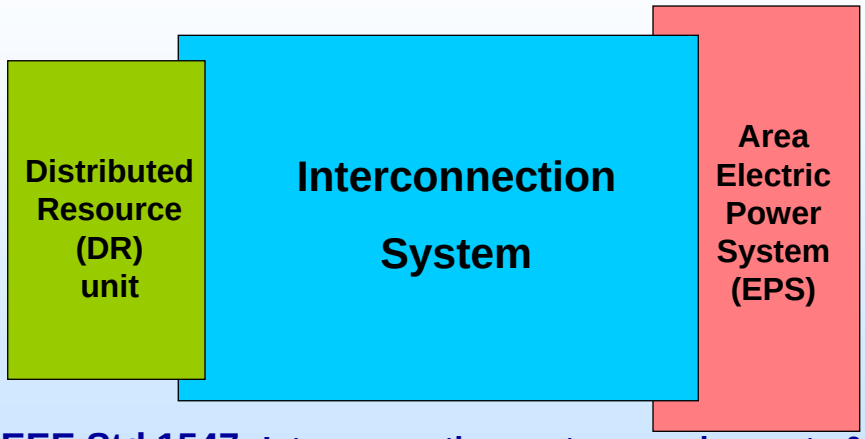
  - the interconnection test
- **Technology neutral,** e.g., does not specify particular equipment nor type
- **A single (whole) document** of mandatory, uniform, universal, requirements.
- **Should be sufficient** for most installations.

IEEE 1547.1 IS:
Test Procedures
Conformance to 1547

IEEE 1547 Is NOT:

- a design handbook
- an application guide
- an interconnection agreement
- prescriptive, e.g., does not address DR self-protection, nor planning, designing, operating, or maintaining the Area EPS.

Std 1547: Interconnection Is The Focus



IEEE Std 1547: Interconnection system requirements & specifications, and test requirements & specifications

1547 DR Interconnection

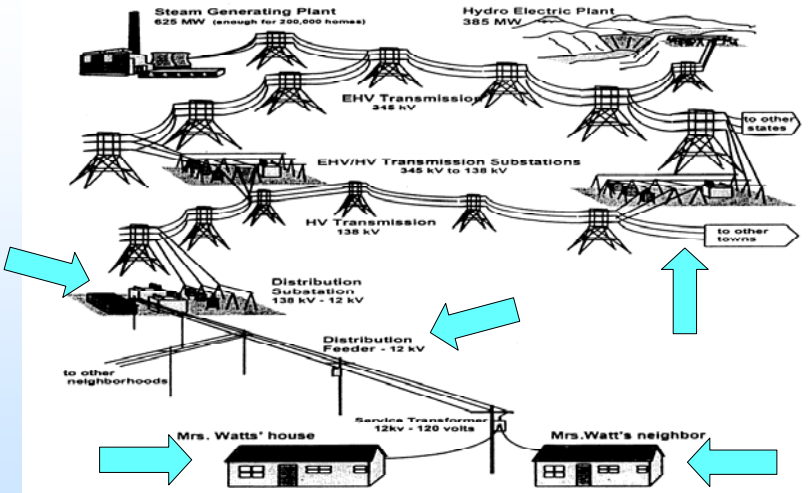
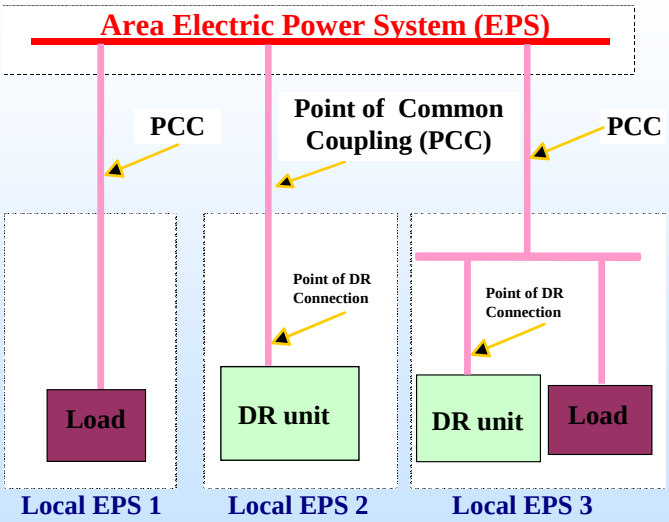


Figure 7.8 A power system consists of several levels: generation, extra high voltage (EHV) transmission, high voltage (HV) transmission, distribution, and utilization.

IEEE 1547 Definitions

- **Distributed Resource (DR)** – sources of electric power that are not directly connected to a bulk power transmission system
- **Electric Power System (EPS)** – facilities that deliver power to a load
- **Interconnection** – the result of the process of adding a DR unit to an area EPS
- **Interconnection Equipment** – individual or multiple devices used in an interconnection system
- **Interconnection System** – the collection of all interconnection equipment, taken as a group, used to interconnect a DR unit(s) to an area EPS

1547 Interconnection Terms



Note: There can be any number of Local EPSs.

IEEE Std 1547

4.0 INTERCONNECTION TECHNICAL SPECIFICATIONS AND REQUIREMENTS

- 4.1 General Requirements
- 4.2 Response to Area EPS Abnormal Conditions
- 4.3 Power Quality
- 4.4 Islanding

5.0 INTERCONNECTION TEST SPECIFICATIONS AND REQUIREMENTS

- 5.1 Design Test
- 5.2 Production Tests
- 5.3 Interconnection Installation Evaluation
- 5.4 Commissioning Tests
- 5.5 Periodic Interconnection Tests

- **ANNEX A (INFORMATIVE) BIBLIOGRAPHY**

4.0 INTERCONNECTION TECHNICAL SPECIFICATIONS AND REQUIREMENTS

4.1 General Requirements

- Voltage Regulation
- Integration with Area EPS Grounding
- Synchronization
- DR on Secondary Grid and Spot Networks
- Inadvertent Energizing of the Area EPS
- Monitoring Provisions
- Isolation Device
- Interconnect Integrity

4.2 Response to Area EPS Abnormal Conditions

- Area EPS Faults
- Area EPS Reclosing Coordination
- Voltage
- Frequency
- Loss of Synchronism
- Reconnection to Area EPS

4.0 Interconnection Technical Specifications and Requirements (end)

4.3 Power Quality

- Limitation of DC Injection
- Limitation of Voltage Flicker Induced by the DR
- Harmonics

4.4 Islanding

- Unintentional Islanding
- Intentional Islanding

5.0 INTERCONNECTION TEST SPECIFICATIONS AND REQUIREMENTS

5.1 Design Test

- Abnormal voltage and frequency
- Synchronization
- Interconnection integrity
- Unintentional islanding
- Limitation of DC injection
- Harmonics

5.0 INTERCONNECTION TEST SPECS AND REQS (cont'd)

5.2 Production Tests

- Meet requirements of:
  - response to abnormal voltage and frequency
  - synchronization
  - may be performed at the factory or at time of commissioning

5.3 Interconnection Installation Evaluation

- Grounding Integration with area EPS
- Isolation Device
- Monitoring provisions
- Area EPS faults
- Area EPS reclosing coordination

5.0 INTERCONNECTION TEST SPECS AND REQS (end)

5.4 Commissioning Tests

- Visual Inspection
- Operability test on the isolation device
- Unintentional islanding functionality test
- Cease to energize functionality test

5.5 Periodic Interconnection Tests

- All interconnection-related protective functions and associated batteries

Annex A. Bibliography

Some Key 1547 Development Issues

that would benefit from further R&D activities

- Develop improved interconnection technology
- Address field testing vs. type testing
- Interconnection equipment certification
- Evaluate secondary grid and spot networks
- Develop grid/DG monitoring and control
- Understand voltage regulation/stability
- Address grounding/faults
- Establish basis for DG penetration/aggregation
- Develop islanding methods and requirements

Some Key 1547 Development Issues

issues not normally addressed as IEEE universal, mandatory requirements

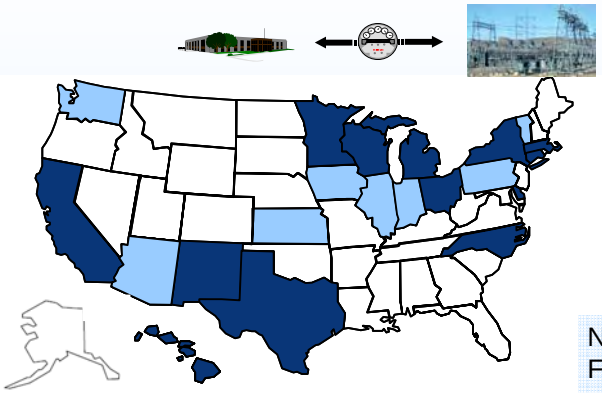
- **Federal/State Implementation and Impacts (rules)**
- **Fully Commercialized/Certified Products, After Sale Support, Warranties**
- **Liability (DG vs. grid operators)**
- **Functionality of Interconnection Package (always more to add)**
- **Lower Interconnection System Cost**
- **Cost of EPS Re-Fit (how and who pays)**
- **Operation (which standard and who is in control)**
- **Reliability (operational issues – durability vs. availability)**
- **Misunderstanding/Misapplication (limited experience/knowledge)**
- **User Disagreement (not all utilities and DGs are alike)**

OUTLINE

- Summary Presentation
  ---------- ----------
- Background
- 1547 Series of Standards
  - IEEE Std 1547 (2003): Standard for interconnecting (system and interconnection test requirements and specifications)
  - IEEE Std 1547.1 (2005) Standard for interconnection conformance test procedures
  - P1547.2 Guide to 1547 standard
  - P1547.3 Guide for information exchange for DR interconnected with EPS
  - P1547.4 Guide for DR island systems
  - P1547.5 Guide for interconnection to transmission grid
  - P1547.6 Recommended Practice for DR in Distribution Networks

➢ Adopting Standards; Testing & Certification

States with Interconnection Mandates



Note:
FERC, RTOs/ISOs, and others are in process or are considering interconnection.

Adopting Consensus Technical Standards

- Require the standard(s) in-toto, as the baseline(s)
- As necessary, clearly state specific exceptions or clarifications
- Any additional requirements need to be analyzed regarding their compatibility and impact on all the baseline standards (not just compared to a single entry)
- Test/conformance evaluation requirements/impacts need to be considered for exceptions and additions
- Installation and operational requirements/impacts also need to be considered for exceptions and additions
- Validation/acceptance should be proven for the modified set of requirements, and for the processes e.g., equipment, personnel and know-how/practices

Adopting Consensus Technical Standards

- Maintain openness in adoption processes (such as revision/change process or implementation process)
- Consensus nature should be maintained, e.g., don't have one stakeholder group take charge
- Impartial/third-party experts should be engaged
- Documentation/Reporting/Labeling needs to be considered
- Changing technologies, problems, and unforeseen events/actions need to be considered/resolved
- **Certification/Accreditation needs to be addressed**

NREL Model 1547 Pre-certification and Certification Program for DG Interconnection Systems*

DRAFT Design for Utility, State, etc.Certification Interconnection Program

STEP 1	**Interconnection System Pre-Certified to IEEE 1547** □Temperature Stability □Response to Abnormal Voltage □Response to Abnormal Frequency □Synchronization □Protection from EMI □Surge Withstand □Paralleling Device □DC Injection □Unintentional Islanding □Reverse Power □Cease to Energize/Loss of Phase □Reconnect after disturbance □Harmonics	**Responsible Organization** Nationally Recognized Test Lab (NRTL) (e.g. UL, CSA)
STEP 2	**Interconnection System Meets IEEE 1547 Requirements** □Voltage Regulation □Integration with Area EPS grounding □Monitoring Provisions □Isolation Device □Recloser Coordination □Flicker	Local Distribution Utility
STEP 3	**Interconnection System Installation** □Installation per NEC or local codes □Commissioning Test per IEEE 1547	Local Electrical Inspector System Installer
STEP 4	**Additional Utility Operator Requirements** □ Monitoring Provisions □ Metering Requirements □ Additional Requirements	Approval Authority
	Utility/State/etc. Interconnection System Approved	

Interconnection Systems are pre-certified using the type tests in IEEE 1547.1 by a NRTL.

The local distribution utility reviews the interconnection system for compatibility to the Area EPS per IEEE 1547

These will be based on a review of the current utiltiy interconnection requirements and all the utilities in it area

Pre-Certified to IEEE 1547

Certified to IEEE 1547

Operator Entity Approved

• A pilot implementation plan should be developed to test the approval process with NREL providing technical expertise and testing support on a case by case basis (WFO) , developing test methods and standards, and conducting round-robin testing to verify every testing entity is conducting the tests as prescribed in 1547 and 1547.1.

* **Interconnection System** - the collection of all interconnection equipment and functions, taken as a group, used to interconnect a DR unit(s) to an Area EPS. (as defined in IEEE 1547)

Prepared By:
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2-20-2004

NREL DER Test Facility

Distributed Energy Resources


Fuel Cell


PV


Microturbine


Wind


Energy Storage


Generator

Interconnection Technologies

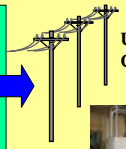

Inverter

Functions

- •Power Conversion
- •Power Conditioning (PQ)
- •Protection
- •DER and Load Control
- •Ancillary Services
- •Communications
- •Metering


Switchgear, Relays, & Controls

Electric Power Systems


Utility Grid


Grid Simulator; Microgrid

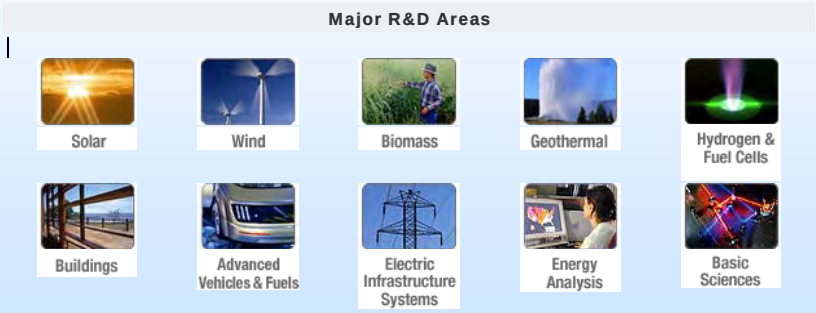
Loads

Loads; loads simulator

Are We There Yet?

- Standards Are Being Developed and Validated In a Timely, Ongoing and Cohesive Manner.
- Advanced Technology Development Is Successfully Incorporating Next Generation Standardized Functionalities.
- Standardization Is Enhancing Systems Integration of Sound Distributed Energy Resources With The Grid That Are Contributing To Modernizing Our Electric Infrastructure.

The National Renewable Energy Laboratory (NREL) is a leader in the U.S. Department of Energy's effort to secure an energy future for the nation that is environmentally and economically sustainable.



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National Renewable Energy Laboratory www.nrel.gov

- Only national laboratory ***dedicated*** to renewable energy and energy efficiency R&D
- Research spans fundamental ***science*** to ***technology*** solutions
- ***Collaboration*** with industry and university partners is a hallmark
- Research programs ***linked*** to market opportunities

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***** NREL DEER Distribution & Interconnection R&D

- **NREL** http://www.nrel.gov
  1617 Cole Blvd. MS-1614 Golden, CO 80401-3393

- **IEEE SCC21 -- IEEE Standards Coordinating Committee 21** on Fuel Cells, Photovoltaics, Dispersed Generation, & Energy Storage
  http://grouper.ieee.org/groups/scc21/
- **IEEE Std 1547 Series of Interconnection Standards** --
  http://grouper.ieee.org/groups/scc21/dr_shared/